AMENDED CLAIMS

[Received by the International Bureau on 19 January 2005 (19.01.05): original claims 1-56 replaced by amended claims 1-50 (17 pages)]

Having thus described the invention, what is claimed as new and secured by Letters Patent is:

1. A method for detection and location of a target crossing into an area defined by a sensor cable, comprising:

generating a TX signal and transmitting same over a first transmission line of the sensor cable, for creating an electromagnetic field;

detecting an RX signal induced in a second transmission line of the cable by the electromagnetic field and identifying in the RX signal a contra-directional reflection received from a target and a co-directional reflection received from the far-end (F) of the first transmission line; and

processing the contra-directional reflection for providing a first coordinate (*R*) of the target, and processing the co-directional reflection for providing a second coordinate (*Z*) of the target.

2. The method as claimed in claim 1, wherein the TX signal is comprised of successive coded pulse sequences selected to achieve a thumbtack correlation in the RX signal at a plurality *B* of points along the sensor cable, defined as range bins.

3. The method as claimed in claim 1, wherein the TX signal is a coded pulse sequence comprising a phase coded pulse of *m* chips, a first *p*-chip long logic "0", a complement of the phase-coded pulse, and a second *p*-chip long logic "0" modulated over a carrier signal of frequency *fc* in the HF/VHF transmission band, a chip having a duration of *n* synchronous cycles of the *fc*.

4. The method as claimed in claim 3, wherein the step of detecting comprises digitizing the RX signal at twice the chip rate for the duration $M=2(m+p)$ of one coded pulse sequence.

5. The method as claimed in claim 2, wherein the second coordinate Z is obtained from a target location signal detected in a range bin at the far-end (F), to provide a measure of the co-directional reflection.

6. The method as claimed in claim 2, wherein the first coordinate R is derived from a target location signal detected in all range bins along the sensor cable, to provide a measure of the contra-directional reflection.

7. The method as claimed in claim 3, wherein the sample rate is half the pulse width to ensure that a target location signal is detected in three consecutive range bins.

8. The method as claimed in claim 3, wherein the step of processing comprises:

detecting a target location signal in three consecutive range bins;

linearly interpolating the amplitude of the target location signal over the three range bins for identifying the general location of the target within the range bin;

within the target bin, determining a group of target sub-bins based on the phase difference $\Delta\Phi$ of the target location signal with respect to the TX signal; and

within the group of target sub-bins, determining a target sub-bin based on the relative phase angle $\Delta\Phi$.

9. The method as claimed in claim 8, further comprising providing a threshold for each range sub-bin and calibrating the thresholds to distinguish a target's presence from environmental changes on the surface of the sensor cable.

10. The method as claimed in claim 1, wherein the step of processing the co-directional reflection comprises determining an end range bin where the co-directional reflection is generated in the absence of a target and

measuring a reference co-directional clutter generated in the end range bin.

11. The method as claimed in claim 10, wherein the step of processing the co-directional reflection further comprises measuring a target co-directional clutter generated in the end range bin; and comparing the target co-directional clutter with the reference co-directional clutter for determining the second coordinate Z of the target.

12. An intrusion detection sensor comprising:

means for generating a TX signal and transmitting same over a first open transmission line, for creating an electromagnetic field;

means for converting an RX signal induced in a second open transmission line by the electromagnetic field into an in-phase (I) component and a quadrature-phase (Q) component for each of a plurality B of range bins corresponding to a respective linear distance R;

means for processing the I and the Q components for each range bin for detecting a target and specifying coordinates R and Z of the target,

wherein R is a linear distance along the first transmission line and Z is a radial distance from the first transmission line. .

13. The sensor as claimed in claim 12, wherein the means for generating comprises:

a TX code generator for generating a coded pulse sequence comprising a phase-coded pulse of m chips, a first p-chip long logic "0", a complement of the phase-coded pulse, and a second p-chip long logic "0";

a pseudo-noise generator for mixing the coded pulse sequence with a pseudo-noise signal for uniformly spreading the spectrum of the coded pulse sequence; and

means for modulating the coded pulse sequence over the carrier signal to obtain the TX signal.

14. The sensor as claimed in claim 13, wherein the means for converting comprises:

means for synchronously detecting an in-phase (I) sample and a quadrature-phase (Q) sample of the RX signal;

a RX code generator for generating a synchronous version of the coded pulse sequence, with a chip rate twice the chip rate of the TX signal;

means for accumulating B consecutive I samples and Q samples, while demodulating the pseudo-noise code from each sample and for simultaneously correlating the version of the coded pulse sequence with each of the I and Q samples, respectively, for creating the I component and Q component, wherein each the I and Q sample is time stamped to specify a range bin.

15. The sensor as claimed in claim 14, wherein the means for synchronously detecting comprises:

a first and a second mixer for combining the carrier signal and a quadrature version of the carrier signal with the RX signal and providing an in-phase and a quadrature-phase demodulated version of the RX signal, respectively; and

a first and a second analog to digital converter for sampling the in-phase and the quadrature-phase demodulated version of the RX signal, respectively for obtaining the I sample and the Q sample.

16. The sensor as claimed in claim 12, wherein the means for processing comprises:

means for filtering the I component and the Q component for obtaining a clutter in-phase term IC and a clutter quadrature-phase term QC, respectively;

means for subtracting the IC term and the QC term from the I component and the Q component respectively for obtaining an in phase incremental variation in magnitude (δIT) and a quadrature-phase

incremental variation in magnitude (δQT) introduced by a target response in the RX signal;

first calculating means for receiving the IC and QC terms and the incremental variations δIT and δQT and calculating a X response in phase with a co-directional clutter and a Y response in quadrature with the co-directional clutter for a range bin where the co-directional clutter is generated; and

second calculating means for receiving the X and Y responses and the incremental variations δIT and δQT and calculating a target location signal for all range bins where the contra-directional clutter is generated.

17. The sensor as claimed in claim 16, wherein the means for processing further comprises target location means for detecting a local peak in the target signal, and generating a target sub-bin signal identifying a target bin and a target sub-bin associated with the local peak.

18. The sensor as claimed in claim 17, wherein the means for processing further comprises detection means for specifying the coordinates R and Z of the target whenever the target sub-bin signals exceeds a threshold corresponding to the target sub-bin.

19. The sensor as claimed in claim 17, wherein the means for processing further comprises calibration means for determining a threshold for each range sub-bin.

20. The sensor as claimed in claim 17, further comprising a tamper alarm unit for declaring a tamper alarm upon detection of a significant change in the co-directional clutter.

21. An intrusion detection system, comprising:

a sensor cable with a first and a second open transmission line, for deployment along a boundary of an area of interest;

means for generating a TX signal and transmitting same over the first transmission line of the sensor cable, for creating an electromagnetic field;

means for detecting an RX signal induced in the second transmission line by the electromagnetic field and identifying in the RX signal a contra-directional reflection received from a target and a co-directional reflection received from the far-end (F) of the first transmission line; and

means for processing the contra-directional reflection for providing a first coordinate (*R*) of the target, and processing the co-directional reflection for providing a second coordinate (*Z*) of the target.

22. The system as claimed in claim 21, further comprising a time-delayed reflector at the far-end (F) of the sensor cable to provide a significant co-directional reflection.

23. The system as claimed in claim 22, wherein the reflector is a termination lead-out with an impedance different form the impedance of the sensor cable.

24. The system as claimed in claim 21, further comprising a second sensor cable, wherein the means for generating generates a second TX signal orthogonal to the TX signal.

25. A method for detection and location of a target crossing a boundary, comprising:

deploying a sensor cable with a first and a second open transmission line along the periphery of an area of interest;

generating a TX signal and transmitting same over the first transmission line, for creating an electromagnetic field;

converting an RX signal induced in a second transmission line by the electromagnetic field into an in-phase (*I*) component and a quadrature-

phase (Q) component for each of a plurality *B* of range bins corresponding to a respective linear distance along the sensor cable;

processing the *I* and the Q components for each the range bin for detecting the target and specifying the coordinates *R* and *Z* of the target,

wherein *R* is a linear distance measured along the cable, and Z is a radial distance from the cable.

26. The method as claimed in claim 25, wherein the step of generating comprises

generating a coded pulse sequence including a phase-coded pulse of *m* chips, a first *p*-chip long "0", a complement of the phase-coded pulse, and a second *p*-chip long "0"; and

modulating a carrier signal of frequency *fc* with the coded pulse sequence mixed with pseudo-noise,

wherein a chip has a duration of *n* synchronous cycles of the *fc*, and wherein the *m* and *p* are selected according to the length *L* of the sensor cable to achieve a thumbtack correlation in each of the *B* range bins.

27. The method as claimed in claim 26, wherein the value for *p* is selected for ensuring that the phase-coded pulse and the complement do not propagate along the first transmission line at the same time.

28. The method as claimed in claim 25, wherein the step of converting comprises:

synchronously detecting an in-phase (*I*) sample and a quadrature-phase (Q) sample of the RX signal;

accumulating *B* consecutive *I* samples and the Q samples, while demodulating the pseudo-noise code from each the sample;

generating a synchronous version of the coded pulse sequence with a chip rate twice the chip rate in the TX signal;

correlating the version of the coded pulse sequence with each of the *B* *I* and Q samples, respectively, for creating the *I* component and Q

component, wherein each I and Q sample is time stamped to specify a range bin.

29. The method as claimed in claim 28, wherein the step of synchronously detecting comprises:

combining the carrier signal and a quadrature version of the carrier signal with the RX signal and providing an in-phase and a quadrature-phase demodulated version of the RX signal, respectively; and

sampling the in-phase and the quadrature-phase demodulated version of the RX signal, respectively, for obtaining the respective I sample and Q sample..

30. The method as claimed in claim 26, wherein the step of processing comprises:

filtering the I component and the Q component for obtaining a clutter in-phase term IC and a clutter quadrature-phase term QC, respectively;

subtracting the IC term and the QC term from the I component and the Q component respectively for obtaining a respective in-phase incremental variation in magnitude (δIT) and a quadrature incremental variation in magnitude (δQT) introduced by a target response in the RX signal;

calculating from the IC and QC terms and the incremental variations δIT and δQT a X response in phase with a co-directional clutter and a Y response in quadrature with the co-directional clutter for a range bin where the co-directional clutter is generated; and

calculating from the X and Y responses and the incremental variations δIT and δQT a target location signal for all range bins where the contra-directional clutter is generated.

31. The method as claimed in claim 30, wherein the step of detecting comprises:

detecting a local peak in the target signal;

within all range bins where the contra-directional clutter is generated, identifying a group of neighbouring range bins affected by the local peak; and

within the group of range bins, identifying the target bin by linearly interpolating the amplitude of the target location signal for the neighbouring range bins.

32. The method as claimed in claim 31, wherein the step of detecting further comprises:

within the target bin, determining a group of target sub-bins based on the phase difference $\Delta\Phi$ between the *I* and *Q* components; and

within the group of target sub-bins, determining a target sub-bin based on the number of cycles in the $\Delta\Phi$.

33. The method as claimed in claim 30, wherein the step of processing further comprises determining a threshold for each range sub-bin in the absence of the target.

34. The method as claimed in claim 31, wherein the step of processing further comprises identifying a target sub-bin where the target location signal exceeds a threshold associated with the target sub-bin; and specifying the coordinates *R* and *Z* of the target.

35. A method for detection and location of a target crossing into an area defined by a sensor cable, comprising:

generating a TX signal and transmitting same over a transmission line of the sensor cable, for creating an electromagnetic field;

receiving a coupled signal in the transmission line and separating an RX signal from the coupled signal in the transmission line caused by the target disturbing the electromagnetic field;

detecting the RX signal and identifying in the RX signal a contra-directional reflection received from the location of the target; and

processing the contra-directional reflection for providing a range of the target.

36. The method as claimed in claim 35, wherein said TX signal is a coded pulse sequence comprising a phase coded pulse of *m* chips, a first *p*-chip long logic "0", a complement of said phase-coded pulse, and a second *p*-chip long logic "0" modulated over a carrier signal of frequency *fc* in the HF/VHF transmission band, a chip having a duration of *n* synchronous cycles of said *fc*.

37. The method as claimed in claim 36, wherein the step of detecting comprises digitizing said RX signal at twice the chip rate for the duration $M=2(m+p)$ of one coded pulse.

38. An intrusion detection sensor comprising:

means for generating a TX signal and transmitting same over a transmission line, for creating an electromagnetic field;

a directional coupler for detecting a coupled signal in the transmission line and for separating an RX signal from the coupled signal in the transmission line, caused by a target disturbing the electromagnetic field;

means for converting the RX signal into an in-phase (*I*) component and a quadrature-phase (Q) component for each of a plurality B of range bins corresponding to a respective linear distance (*R*); and

means for processing the *I* and the Q components for each range bin for detecting the target and specifying coordinates *R* and *Z* of the target,

wherein *R* is a linear distance along the transmission line and *Z* is a radial distance from the transmission line.

39. The sensor as claimed in claim 38, wherein the means for converting comprises:

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means for synchronously detecting an in-phase (*I*) sample and a quadrature-phase (*Q*) sample of the RX signal;

a RX code generator for generating a synchronous version of the coded pulse sequence, with a chip rate twice the chip rate of the TX signal;

means for accumulating *B* consecutive *I* samples and *Q* samples, while demodulating the pseudo-noise code from each the samples and for simultaneously correlating the version of the coded pulse sequence with each of the *I* and *Q* samples, respectively, for creating the *I* component and *Q* components, wherein each the *I* and *Q* sample is time stamped to specify a range bin.

40. An intrusion detection system, comprising:

a sensor cable with a transmission line, for deployment along a boundary of interest;

means for generating a TX signal and transmitting same over a transmission line of the sensor cable, for creating an electromagnetic field;

a directional coupler for detecting a coupled signal in the transmission line and for separating an RX signal from the coupled signal in the transmission line caused by the target disturbing the electromagnetic field;

means for detecting the RX signal and identifying in the RX signal a contra-directional reflection received from the location of the target; and

means for processing the contra-directional reflection for providing a range of the target.

41. A method for detection and location of a target crossing a boundary, comprising:

deploying a sensor cable having a transmission line along the periphery of an area of interest;

generating a TX signal and transmitting same over the transmission line, for creating an electromagnetic field;

receiving a coupled signal and separating an RX signal from the coupled signal in the transmission line caused by the target disturbing the electromagnetic field;

converting the RX signal into an in-phase (*I*) component and a quadrature-phase (Q) component for each of a plurality B of range bins corresponding to a respective linear distance *R*;

processing the *I* and the Q components for each range bin for detecting the target and specifying the coordinates *R* and *Z* of the intruder,

wherein *R* is a linear distance measured along the cable, and *Z* is a radial distance from the cable.

42. A method for detection and location of a target crossing into an area defined by a sensor cable, comprising:

generating a first TX signal and transmitting the first TX signal over a first transmission line of the sensor cable and simultaneously generating a second TX signal and transmitting the second TX signal over a second transmission line of the sensor cable, for creating an electromagnetic field;

receiving a first coupled signal corresponding to the first TX signal in the first transmission line and separating a first RX signal from the first coupled signal in the first transmission line caused by the target disturbing the electromagnetic field, and simultaneously receiving a second coupled signal corresponding to the second TX signal in the second transmission line and separating a second RX signal from the second coupled signal in the second transmission line caused by the target disturbing the electromagnetic field;

detecting the first RX signal and identifying in the first RX signal a first contra-directional reflection received from the location of the target, and simultaneously detecting the second RX signal and identifying in the second RX signal a second contra-directional reflection received from the location of the target;

correlating the first and the second contra-directional reflection; and

processing the correlated first and second contra-directional reflection to provide a range of the target.

43. The method as claimed in claim 42, wherein the first TX signal is a coded pulse sequence comprising a phase coded pulse of *m* chips, a first *p*-chip long logic "0", a complement of the phase-coded pulse, and a second *p*-chip long logic "0" modulated over a carrier signal of frequency *fc* in the HF/VHF transmission band, a chip having a duration of *n* synchronous cycles of the fc; and wherein the second TX signal is a coded pulse sequence comprising a phase coded pulse of *m* chips, a first *p*-chip long logic "0", a complement of the phase-coded pulse, and a second *p*-chip long logic "0" modulated over a carrier signal of frequency *fc* in the HF/VHF transmission band, a chip having a duration of *n* synchronous cycles of the fc.

44. The method as claimed in claim 43, wherein the step of detecting the first RX signal comprises digitizing the first RX signal at twice the chip rate for the duration $M=2(m+p)$ of one coded pulse sequence, and wherein the step of detecting the second RX signal comprises digitizing the second RX signal at twice the chip rate for the duration $M=2(m+p)$ of one coded pulse sequence.

45. An intrusion detection sensor comprising:

means for generating a first TX signal and transmitting same over a first transmission line of a sensor cable, for creating an electromagnetic field;

means for simultaneously generating a second TX signal and transmitting same over a second transmission line of the sensor cable, for creating an electromagnetic field;

a first directional coupler for detecting a first coupled signal in the first transmission line corresponding to the first TX signal, and separating a first RX signal from the first coupled signal in the first transmission line, caused by a target disturbing the electromagnetic field;

a first means for converting the first RX signal into a first in-phase (*I*) component and a first quadrature-phase (*Q*) component for each of a plurality of range bins corresponding to a respective linear distance R;

a second directional coupler for simultaneously detecting a second coupled signal in the second transmission line corresponding to the second TX signal, and separating a second RX signal from the second coupled signal in the second transmission line, caused by a target disturbing the electromagnetic field;

a second means for converting the second RX signal into a second in-phase (*I*) component and a second quadrature-phase (*Q*) component for each of the plurality of range bins corresponding to the respective linear distance *R*;

means for processing the first and the second *I* and the *Q* components for each range bin for detecting the target and specifying coordinates *R* and *Z* of the target,

wherein *R* is a linear distance along the transmission line and *ZR* is the ratio of distances to the first and the second transmission lines.

46. The sensor as claimed in claim 45, wherein the first means for converting comprises:

a first means for synchronously detecting a first in-phase (*I*) sample and a first quadrature-phase (*Q*) sample of the first RX signal;

a first RX code generator for generating a first synchronous version of the coded pulse sequence, with a chip rate twice the chip rate of the first TX signal;

a first means for accumulating first set of *B* consecutive *I* and *Q* samples, while demodulating the pseudo-noise code from each of the first set of samples and for simultaneously correlating the first version of the coded pulse sequence with each of the first set of *I* and *Q* samples, respectively, for creating the first *I* component and the first *Q* component, wherein each of the first set of *I* and *Q* samples are time stamped to

specify a range bin; and wherein the second means for converting comprises:

a second means for synchronously detecting a second in-phase (*I*) sample and a second quadrature-phase (Q) sample of the second RX signal;

a second RX code generator for generating a second synchronous version of the coded pulse sequence, with a chip rate twice the chip rate of the TX signal;

a second means for accumulating second set of *B* consecutive *I* and *Q* samples, while demodulating the pseudo-noise code from each the second set of samples and for simultaneously correlating the second version of the coded pulse sequence with each of the second set of *I* and *Q* samples, respectively, for creating the second *I* component and the second *Q* component, wherein each of the second set of *I* and *Q* samples are time stamped to specify a range bin.

47. An intrusion detection system, comprising:

a sensor cable with a first and a second transmission line, for deployment along a boundary of an area of interest;

means for generating a first TX signal and transmitting the first TX signal over the first transmission line of the sensor cable and means for simultaneously generating a second TX signal and transmitting the second TX signal over the second transmission line of the sensor cable, for creating an electromagnetic field;

a first directional coupler for receiving a first coupled signal corresponding to the first TX signal in the first transmission line and separating a first RX signal from the first coupled signal in the first transmission line caused by the target disturbing the electromagnetic field;

means for detecting the first RX signal and identifying in the first RX signal a first contra-directional reflection received from the location of the target;

a second directional coupler for simultaneously receiving a second coupled signal corresponding to the second TX signal in the second transmission line and separating a second RX signal from the second coupled signal in the second transmission line caused by the target disturbing the electromagnetic field;

means for detecting the second RX signal and identifying in the second RX signal a second contra-directional reflection received from the location of the target;

means for correlating the first and the second contra-directional reflection; and

means for processing the correlated first and second contra-directional reflection to provide a range of the target.

48. A method for detection and location of a target crossing a boundary, comprising:

deploying a sensor cable, having a first and a second transmission line, along the periphery of an area of interest;

generating a first TX signal and transmitting the first TX signal over the first transmission line of the cable;

simultaneously generating a second TX signal and transmitting the second TX signal over the second transmission line of the sensor cable, for creating an electromagnetic field;

detecting a first coupled signal in the first transmission line, and separating a first RX signal from the first coupled signal in the first transmission line caused by the target disturbing the electromagnetic field;

converting the first RX signal into an first in-phase (*I*) component and a first quadrature-phase (Q) component for each of a plurality B of range bins corresponding to a respective linear distance along the sensor cable;

simultaneously detecting a second coupled signal in the second transmission line, and separating a second RX signal from the second coupled signal in the second transmission line caused by the target disturbing the electromagnetic field;

converting the second RX signal into an second in-phase (*I*) component and a second quadrature-phase (Q) component for each of the plurality B of range bins corresponding to the respective linear distance along the sensor cable; and

processing the first and the second *I* and the Q components for each the range bin for detecting the target and specifying the coordinates *R* and *Z* of the intruder,

wherein *R* is a linear distance measured along the cable, and ZR is the ratio of distances to the first and the second transmission lines.

49. The method as in claim 42 and 48, wherein the step of processing includes determining velocity of the target based on a timing differential between the first and the second coupled signal.

50. The method as in claim 42 and 48, wherein the step of processing includes determining range of the target based on a phase differential between the first and the second coupled signal.